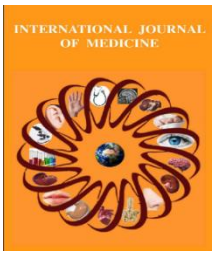

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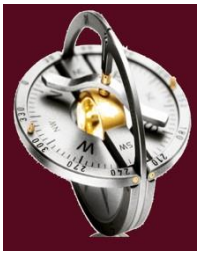

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Original Research

CLINICAL PROFILE AND PREDICTORS OF DELAYED FRACTURE HEALING IN PATIENTS WITH DIABETES MELLITUS: A PROSPECTIVE OBSERVATIONAL STUDY.

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Abstract

Background: Diabetes mellitus is associated with impaired bone metabolism and delayed fracture healing due to persistent hyperglycaemia, microvascular dysfunction, chronic inflammation, and altered osteoblast activity. Delayed fracture union contributes to prolonged disability, repeated surgical interventions, and increased healthcare costs. Identifying predictors of delayed fracture healing is essential for improving patient outcomes. *Aim:* To evaluate the clinical profile and identify predictors of delayed fracture healing among patients with diabetes mellitus presenting with fractures in a tertiary care teaching hospital.

Objectives:

1. To study the demographic, clinical, biochemical, and fracture characteristics of patients with diabetes mellitus presenting with fractures.
2. To identify clinical and biochemical predictors associated with delayed fracture healing in patients with diabetes mellitus.

Materials and Methods: A prospective observational study was conducted among **50 adult patients** with diabetes mellitus presenting with radiologically confirmed fractures at a tertiary care teaching hospital. Demographic characteristics, duration of diabetes, HbA1c, diabetic complications, fracture characteristics, treatment modality, and follow-up findings were recorded. Fracture healing was assessed clinically and radiologically at regular follow-up visits. Data were analyzed using SPSS version 26.0. *Results:* The mean age of the study participants was 55.2 ± 12.4 years, with males constituting 62.0% of the study population. Type 2 diabetes mellitus was present in 94.0% of patients. Delayed fracture healing occurred in 16 patients (32.0%), whereas 34 patients (68.0%) achieved normal fracture union. Patients with delayed healing were significantly older (62.4 ± 10.8 vs. 51.8 ± 11.6 years; p=0.003) and had significantly higher HbA1c levels (9.7 ± 1.2% vs. 7.7 ± 1.1%; p<0.001). Diabetes duration greater than 10 years, peripheral neuropathy, peripheral arterial disease, smoking, obesity, open fractures, comminuted fractures, and post-treatment infection showed significant associations with delayed fracture healing on univariate analysis. Multivariable logistic regression demonstrated that HbA1c ≥9% (Adjusted OR 5.86; p=0.007), diabetes duration >10 years (Adjusted OR 3.42; p=0.035), peripheral neuropathy (Adjusted OR 4.13; p=0.027), open fractures (Adjusted OR 3.64; p=0.045), and post-treatment infection (Adjusted OR 5.21; p=0.026) were independent predictors of delayed fracture healing. *Conclusion:* Delayed fracture healing is a common complication among patients with diabetes mellitus. Poor glycaemic control, prolonged duration of diabetes, peripheral neuropathy, open fractures, and post-treatment infection are the major independent predictors of delayed fracture healing. Early optimization of blood glucose, meticulous fracture management, aggressive infection prevention, and close follow-up of high-risk patients may improve fracture union and functional outcomes.

Keywords: *Diabetes mellitus; Fracture healing; Delayed union; HbA1c; Peripheral neuropathy.*

Introduction

Diabetes mellitus (DM) is one of the most prevalent chronic metabolic disorders worldwide and represents a major public health challenge because of its rapidly increasing incidence and the wide spectrum of microvascular and macrovascular complications. According to the International Diabetes Federation (IDF), over 589 million adults were living with diabetes globally in 2024, and this number is projected to exceed 850 million by 2050. India bears a disproportionate burden of the disease, with more than 100 million individuals affected, making it the country with the second-largest diabetic population in the world.[1] The increasing prevalence of diabetes has resulted in a parallel rise in musculoskeletal complications, including osteoporosis, increased susceptibility to fractures, impaired fracture healing, delayed union, non-union, and postoperative infections.[1,2] Fracture healing is a complex biological process involving sequential phases of inflammation, soft callus formation, hard callus formation, and bone remodeling. Successful healing depends on adequate vascularity, osteogenic cell activity, growth factors, mechanical stability, and an appropriate inflammatory response. Diabetes adversely affects each of these stages through persistent hyperglycaemia, oxidative stress, chronic inflammation, impaired angiogenesis, reduced osteoblast differentiation, excessive osteoclast activity, and accumulation of advanced glycation end products (AGEs). These pathological alterations delay callus maturation, reduce biomechanical strength, and prolong the overall healing period.[3]

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Several experimental and clinical studies have demonstrated that diabetes negatively influences skeletal health by altering bone microarchitecture and reducing bone quality independent of bone mineral density. Hyperglycaemia impairs mesenchymal stem-cell differentiation toward osteoblasts while promoting adipogenesis within the bone marrow. Furthermore, chronic inflammation characterized by elevated tumour necrosis factor-α (TNF-α), interleukin-1β, and interleukin-6 disrupts normal bone regeneration. These mechanisms collectively increase the likelihood of delayed union and non-union following fractures.[4] Patients with diabetes frequently present with additional risk factors such as peripheral neuropathy, peripheral arterial disease, nephropathy, obesity, smoking, and poor glycaemic control, all of which further compromise fracture healing. Delayed diagnosis due to diminished pain perception, recurrent trauma secondary to neuropathy, impaired immune function, and increased susceptibility to infection also contribute to poor clinical outcomes. These factors often necessitate prolonged immobilization, repeated surgical procedures, increased healthcare expenditure, and delayed return to functional activity.[5]

Recent systematic reviews have confirmed that diabetes approximately doubles the risk of impaired fracture healing. Ding et al., in a meta-analysis including more than 5,600 patients, reported that individuals with diabetes had significantly greater odds of delayed union, malunion, and non-union compared with non-diabetic individuals (OR 2.11, 95% CI 1.33-3.37). The risk was particularly high in lower-limb fractures, long-bone fractures, and patients with complicated diabetes, emphasizing the importance of identifying clinical predictors that influence healing outcomes.[6] India is witnessing a rapid epidemiological transition characterized by increasing rates of diabetes, road traffic accidents, osteoporosis, and fragility fractures. Orthopaedic surgeons in tertiary care hospitals are therefore managing an increasing number of diabetic patients presenting with fractures requiring operative or conservative treatment. Despite advances in fixation techniques and perioperative care, delayed fracture healing remains a frequent challenge in this population. However, Indian data evaluating the relationship between patient characteristics, glycaemic control, diabetes duration, diabetic complications, fracture characteristics, and fracture-healing outcomes remain limited. This highlights the need for prospective observational studies in the Indian population to generate locally relevant evidence that can improve patient management and outcomes.[7]

Early identification of predictors associated with delayed fracture healing allows clinicians to optimize glycaemic control, manage associated comorbidities, improve nutritional status, adopt individualized fixation strategies, initiate timely rehabilitation, and closely monitor high-risk patients. Such risk stratification may reduce delayed union, non-union, infection, repeated surgeries, prolonged hospitalization, and functional disability. Therefore, the present study is designed to evaluate the clinical profile of diabetic patients presenting with fractures and to identify independent predictors of delayed fracture healing in a tertiary care teaching hospital.

AIM
To evaluate the clinical profile and identify predictors of delayed fracture healing among patients with diabetes mellitus presenting with fractures in a tertiary care teaching hospital.

OBJECTIVES
1. To study the demographic, clinical, biochemical, and fracture characteristics of patients with diabetes mellitus presenting with fractures.
2. To identify clinical and biochemical predictors associated with delayed fracture healing in patients with diabetes mellitus.

Materials and Methods
Study Design
A Prospective observational study.

Study Population
Adult patients with diabetes mellitus presenting with acute fractures requiring conservative or operative management.

Sample Size
A total of **50 patients** diagnosed with diabetes mellitus and fulfilling the eligibility criteria will be included.

Sampling Technique
Consecutive sampling.

Inclusion Criteria
- Patients aged ≥18 years.
- Diagnosed Type 1 or Type 2 diabetes mellitus.
- Radiologically confirmed acute fracture.
- Patients willing to participate and provide written informed consent.
- Patients available for follow-up until fracture union.

Exclusion Criteria
- Pathological fractures.
- Malignancy involving bone.
- Chronic corticosteroid therapy.
- Chronic liver disease.
- Metabolic bone diseases other than diabetes.
- End-stage renal disease requiring dialysis.
- Polytrauma with life-threatening injuries.
- Patients lost to follow-up.

Data Collection
After obtaining Institutional Ethics Committee approval and written informed consent, eligible patients will be enrolled consecutively. Demographic details, duration of diabetes, treatment history, HbA1c, fasting and postprandial blood glucose, body mass index, smoking, alcohol use, diabetic complications, fracture characteristics, treatment modality, and laboratory investigations will be recorded. Patients will undergo periodic clinical and radiological follow-up at 6, 12, 18, and 24 weeks to assess fracture healing.

Statistical Analysis
Data will be entered into Microsoft Excel and analysed using SPSS version 26.0. Continuous variables will be expressed as mean ± standard deviation, whereas categorical variables will be presented as frequencies and percentages. Independent Student's *t*-test or Mann-Whitney *U* test will compare continuous variables, and Chi-square test or Fisher's exact test will compare categorical variables. Variables significant on univariate analysis will be entered into multivariable logistic regression to identify independent predictors of delayed fracture healing. A p-value <0.05 will be considered statistically significant.

Results

A total of 50 patients with diabetes mellitus and radiologically confirmed fractures were included in the study. Fracture healing was assessed clinically and radiologically during follow-up. Delayed fracture healing was observed in 16 patients (32.0%), while 34 patients (68.0%) achieved union within the expected period.

Table 1. Demographic and clinical profile of the study participants

Variable	Category	Frequency (n=50)	Percentage
Age group	18-40 years	9	18.0
	41-60 years	25	50.0
	>60 years	16	32.0
Sex	Male	31	62.0
	Female	19	38.0
Type of diabetes	Type 1 DM	3	6.0
	Type 2 DM	47	94.0
Duration of diabetes	<5 years	14	28.0
	5-10 years	20	40.0
	>10 years	16	32.0
Glycaemic control	HbA1c <7%	10	20.0
	HbA1c 7-8.9%	22	44.0
	HbA1c ≥9%	18	36.0
Body mass index	Normal	15	30.0
	Overweight	22	44.0
	Obese	13	26.0
Smoking	Present	13	26.0
	Absent	37	74.0

The mean age of the study participants was **55.2 ± 12.4 years**, and the mean duration of diabetes was **8.7 ± 5.1 years**. The mean HbA1c level was **8.4 ± 1.5%**.

Interpretation: Half of the study participants belonged to the 41-60-year age group, and males constituted 62.0% of the study population. Type 2 diabetes was present in 94.0% of patients. Nearly one-third had diabetes for more than 10 years, while 36.0% had poor glycaemic control with HbA1c ≥9%.

Table 2. Distribution of fracture and treatment characteristics

Characteristic	Category	Frequency	Percentage
Mechanism of injury	Road traffic accident	27	54.0
	Fall from standing height	15	30.0
	Fall from height	6	12.0
	Other causes	2	4.0
Anatomical site	Femur	15	30.0
	Tibia	13	26.0
	Ankle/foot	8	16.0
	Upper limb	10	20.0
	Other fractures	4	8.0
Fracture type	Closed	37	74.0
	Open	13	26.0
Fracture pattern	Simple	29	58.0
	Comminuted	21	42.0
Treatment modality	Operative	39	78.0
	Conservative	11	22.0
Post-treatment infection	Present	9	18.0
	Absent	41	82.0
Healing outcome	Normal union	34	68.0
	Delayed healing	16	32.0

Interpretation: Road traffic accidents were the most common mechanism of injury, accounting for 54.0% of fractures. Femoral and tibial fractures together constituted 56.0% of cases. Open fractures were present in 26.0%, while 42.0% had comminuted fractures. Most patients underwent operative treatment, and delayed fracture healing occurred in 32.0%.

Table 3. Association of demographic and diabetes-related factors with delayed fracture healing

Variable	Normal healing (n=34)	Delayed healing (n=16)	Statistical test	p-value
Mean age, years	51.8 ± 11.6	62.4 ± 10.8	Independent *t*-test	**0.003**
Male sex	20 (58.8%)	11 (68.8%)	Chi-square test	0.499
Diabetes duration >10 years	6 (17.6%)	10 (62.5%)	Fisher's exact test	**0.002**
HbA1c ≥9%	6 (17.6%)	12 (75.0%)	Chi-square test	**<0.001**
Mean HbA1c, %	7.7 ± 1.1	9.7 ± 1.2	Independent *t*-test	**<0.001**
Obesity	6 (17.6%)	7 (43.8%)	Fisher's exact test	**0.046**
Smoking	5 (14.7%)	8 (50.0%)	Fisher's exact test	**0.012**
Peripheral neuropathy	5 (14.7%)	10 (62.5%)	Fisher's exact test	**0.001**
Peripheral arterial disease	2 (5.9%)	6 (37.5%)	Fisher's exact test	**0.009**
Diabetic nephropathy	4 (11.8%)	7 (43.8%)	Fisher's exact test	**0.016**

Interpretation: Patients with delayed healing were significantly older and had a longer duration of diabetes and higher mean HbA1c levels. Poor glycaemic control, obesity, smoking, peripheral neuropathy, peripheral arterial disease, and diabetic nephropathy were significantly associated with delayed fracture healing. Sex did not show a statistically significant association.

Table 4. Association of fracture- and treatment-related factors with delayed healing

Variable	Normal healing (n=34)	Delayed healing (n=16)	Statistical test	p-value
Lower-limb fracture	21 (61.8%)	15 (93.8%)	Fisher's exact test	**0.021**
Open fracture	5 (14.7%)	8 (50.0%)	Fisher's exact test	**0.012**
Comminuted fracture	10 (29.4%)	11 (68.8%)	Chi-square test	**0.008**
Operative treatment	25 (73.5%)	14 (87.5%)	Fisher's exact test	0.309
Post-treatment infection	2 (5.9%)	7 (43.8%)	Fisher's exact test	**0.002**
Inadequate reduction/alignment	2 (5.9%)	5 (31.3%)	Fisher's exact test	**0.025**
Weight-bearing before advised period	3 (8.8%)	5 (31.3%)	Fisher's exact test	0.051
Mean time to union, weeks	17.1 ± 3.4	29.8 ± 5.7	Independent *t*-test	**<0.001**

Interpretation: Delayed healing was significantly more frequent among patients with lower-limb fractures, open fractures, comminuted fractures, post-treatment infection, and inadequate fracture reduction. The mean time to union was significantly longer in patients with delayed healing. Treatment modality alone was not significantly associated with the outcome.

Table 5. Multivariable logistic regression analysis of independent predictors of delayed fracture healing

Predictor	Adjusted odds ratio	95% confidence interval	p-value
Age >60 years	2.18	0.68-6.97	0.189
Diabetes duration >10 years	3.42	1.09-10.76	**0.035**
HbA1c ≥9%	5.86	1.62-21.18	**0.007**
Smoking	2.71	0.73-10.06	0.137
Peripheral neuropathy	4.13	1.18-14.43	**0.027**
Peripheral arterial disease	3.27	0.76-14.12	0.112
Open fracture	3.64	1.03-12.88	**0.045**
Comminuted fracture	2.38	0.73-7.80	0.151
Post-treatment infection	5.21	1.22-22.31	**0.026**

Model significance: $p<0.001$;

Interpretation: After adjustment for potential confounding factors, HbA1c ≥9%, diabetes duration exceeding 10 years, peripheral neuropathy, open fracture, and post-treatment infection remained independent predictors of delayed fracture healing. Poor glycaemic control showed the strongest association, with nearly six-fold greater odds of delayed healing.

Discussion

The present prospective observational study evaluated the clinical profile and predictors of delayed fracture healing among diabetic patients presenting with fractures. Delayed fracture healing was observed in 32.0% of patients, indicating that nearly one-third of diabetic individuals experienced prolonged fracture union. This finding is consistent with the systematic review and meta-analysis by **Ding et al.**[8], who reported that diabetes significantly increased the risk of impaired fracture healing compared with non-diabetic individuals (OR 2.11, 95% CI 1.33-3.37), confirming diabetes as an important independent risk factor for delayed union.

The mean age of patients with delayed healing in our study (62.4 ± 10.8 years) was significantly higher than that of patients with normal healing (51.8 ± 11.6 years, $p=0.003$). Increasing age has been associated with reduced osteogenic potential, impaired angiogenesis, and diminished bone remodeling capacity. **Tanios et al.**[9] similarly reported that advancing age, together with diabetes-related metabolic abnormalities, adversely affects every phase of fracture healing through suppression of osteoblast activity and delayed callus maturation.

Poor glycaemic control emerged as the strongest predictor of delayed fracture healing in the present study. Patients with HbA1c ≥9% had significantly higher odds of delayed healing (adjusted OR 5.86, $p=0.007$), and the mean HbA1c among patients with delayed healing was 9.7 ± 1.2%. Hyperglycaemia promotes oxidative stress, advanced glycation end-product accumulation, and chronic inflammation, thereby impairing bone regeneration. Similar observations were reported by **Jiao et al.**[10], who demonstrated that persistent hyperglycaemia reduces osteoblast differentiation, increases osteoclast activity, and delays callus mineralization, ultimately prolonging fracture union.

Longer duration of diabetes was another important determinant of fracture healing. In our study, 62.5% of patients with delayed healing had diabetes for more than ten years compared with only 17.6% in the normal healing group ($p=0.002$). Chronic exposure to hyperglycaemia leads to cumulative microvascular damage and deterioration of bone quality. **Johnson et al.**[11] reported that prolonged diabetes with end-organ damage substantially increases the risk of delayed union, malunion, wound complications, and revision surgery following fractures, particularly in lower-limb injuries.

Peripheral neuropathy showed a strong association with delayed fracture healing in the present study (62.5% vs 14.7%, $p=0.001$) and remained an independent predictor on multivariable analysis (adjusted OR 4.13). Neuropathy contributes to repeated microtrauma, delayed presentation, altered weight-bearing, and impaired vascular responses. These findings are in agreement with **Johnson et al.**[11], who emphasized that complicated diabetes with neuropathy and peripheral arterial disease is associated with prolonged healing and poorer orthopaedic outcomes.

Open fractures and post-treatment infection were also significantly associated with delayed healing in our study. Open fractures were associated with an adjusted OR of 3.64, while post-treatment infection increased the odds of delayed union more than fivefold (adjusted OR 5.21). Infection compromises vascularity, disrupts callus formation, and prolongs inflammation. Similar findings have been described by **Zura et al.**[12], who identified diabetes, infection, and fracture severity as major contributors to fracture non-union.

Lower-limb fractures constituted the majority of delayed healing cases in the present study. This observation is supported by the meta-analysis of **Ding et al.**[8], which demonstrated significantly higher rates of impaired healing in long-bone and lower-extremity fractures among diabetic patients than in non-diabetic controls.

Smoking and obesity were associated with delayed fracture healing on univariate analysis but did not remain independent predictors after multivariable adjustment. These factors likely contribute indirectly by impairing tissue perfusion, increasing oxidative stress, and reducing osteogenic activity. Recent reviews have similarly suggested that smoking and obesity potentiate the adverse effects of diabetes on fracture healing, especially when combined with poor glycaemic control.

The mean time to fracture union was significantly longer among patients with delayed healing (29.8 ± 5.7 weeks) than among those with normal healing (17.1 ± 3.4 weeks, $p<0.001$). This prolonged healing duration reflects the cumulative effects of metabolic dysfunction, impaired angiogenesis, chronic inflammation, and reduced bone turnover in diabetes. Recent systematic evidence continues to support the observation that diabetes substantially increases the likelihood of delayed union and non-union compared with non-diabetic patients.

Overall, the findings of the present study demonstrate that poor glycaemic control, longer duration of diabetes, peripheral neuropathy, open

fractures, and post-treatment infection are the principal predictors of delayed fracture healing. Early optimization of blood glucose, meticulous fracture stabilization, aggressive infection prevention, and close follow-up of high-risk patients may improve fracture union and functional recovery. These findings provide clinically relevant evidence for risk stratification and individualized management of diabetic patients with fractures.

Conclusion

Diabetes mellitus significantly influences the fracture-healing process by impairing bone regeneration and increasing the risk of delayed union. In the present prospective observational study, **32% of diabetic patients developed delayed fracture healing**, highlighting the substantial burden of impaired skeletal repair in this population. Poor glycaemic control (HbA1c ≥9%), longer duration of diabetes (>10 years), peripheral neuropathy, open fractures, and post-treatment infection emerged as significant independent predictors of delayed fracture healing. These findings emphasize the importance of early identification of high-risk patients through comprehensive clinical assessment and metabolic evaluation. Optimizing glycaemic control, preventing infection, ensuring stable fracture fixation, and providing close follow-up can improve fracture healing outcomes and reduce complications. The study provides valuable evidence for risk stratification and individualized management of diabetic patients with fractures in routine orthopaedic practice and may contribute to developing standardized protocols for improving fracture-healing outcomes.

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